# Examining the types, features, and use of instructional materials in afterschool science

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Afterschool programs are increasingly seen as important venues where ambitious science learning can occur. Within the past fifteen years, funding for development and research on out-of-school programming for science has dramatically increased, resulting in the creation of new programs and instructional materials for afterschool science (e.g., Lawrence Hall of Science, 2009; Lyon, Jafri, & St. Louis, 2012) as well as a growing body of research literature (e.g., National Research Council [NRC], 2009). In the area of afterschool programming, research shows that afterschool settings can play a critical role in providing children with access to rich science learning opportunities by substantially expanding the time children have to explore science (Coalition for Science Afterschool, 2007). These opportunities can be considered especially important for elementary-aged children, given the education policy context wherein science instruction in elementary schools is often undervalued and its presence is modest (Marx & Harris, 2006; Banilower et al., 2013).

Beyond simply extending the school day, or providing more school-like instruction after school, afterschool settings offer a unique learning environment often quite different from the traditional school structure (Eccles & Templeton, 2002). While afterschool programming has increasingly focused on academic enrichment, the activities are often infused with a youth development perspective that emphasizes active and collaborative learning, developing a sense of mastery, and meaningful participation (Mahoney, Larson, & Eccles, 2005). By blending science education and youth development perspectives, many programs have demonstrated positive effects, such as improved attitudes toward science and science-related fields and careers, increased science knowledge and skills, and a higher likelihood of graduating and pursuing a science-related career (Chi, Snow, Goldstein, Lee, & Chung, 2010).

In recent years, state educational agencies and funders have begun to invest in large-scale afterschool initiatives. As these initiatives are realized, it will be important to examine how they support science. At the present time, little is known about how to implement high quality science offerings on a broad scale in typical afterschool programs that are not expressly designed as environments for science learning (Noam et al., 2010). There is, for instance, little research on the kinds of instructional materials used in typical, large-scale afterschool programs that provide services to diverse populations of children and implement science in their settings[1]. There is also a need for research on how the instructional materials that afterschool programs do use align with contemporary views on how learners can best be supported in out-of-school settings, such as the principles for science learning described in the National Research Council's synthesis report on informal science learning (NRC, 2009).

In an effort to better understand the conditions under which science is provided in large-scale afterschool initiatives, we investigated the use of science instructional materials within and across sites of a statewide afterschool program in California. The publicly funded initiative provides support for community-based afterschool programming in all regions of the state. Our aim was to gain insight into the types of science instructional materials in use at the afterschool sites, the range of use of different types of materials, the kinds of support features provided within these materials, and how afterschool staff used the materials to plan and enact science.

## Background

### Afterschool Science

The field of afterschool science is growing and garnering increased attention as educators, researchers, and policymakers recognize that the hours after school can provide unique time and structure for engaging children in science. In response, an impressive array of stakeholders –

[1] We distinguish these more "typical" programs from those established solely for the purpose of implementing science education interventions under specialized conditions.

foundations, government agencies, informal science institutions, universities, and national youth organizations – have made investments in providing afterschool opportunities in science. Many recently developed initiatives serve diverse youth populations and aim to increase the participation of low-income youth and underrepresented groups in science, notably minority youth and young women (e.g., Lyon & Jafri, 2010).

Contemporary views on how learners can best be supported in out of school settings have been highlighted in the National Research Council's (NRC) synthesis report, *Learning Science in Informal Environments* (NRC, 2009). The report illustrates how informal learning environments can play a distinct and substantive role in promoting meaningful engagement in science. Moreover, the report recommends that informal learning environments have clear learning goals, are highly interactive, include multiple pathways for children to engage with science, facilitate science learning across settings, promote engagement and learning over extended time, and draw upon children's interests, experiences, and prior knowledge to support rich learning (NRC, 2009). These recommendations reflect the emerging consensus on key principles that bring together views on science learning with youth development perspectives.

Although there is generally wide agreement about the tremendous potential for afterschool programs to accommodate powerful science learning experiences, there is evidence that these settings have their own challenges that can make it hard to enact science well. For instance, afterschool staff members responsible for enacting science with children often have neither a science background nor an understanding of how to orchestrate rich science activities (e.g., Noam, Dahlgren, Larson, & Dorph, 2008). Moreover, high turnover of staff is a persistent problem (Dennehy & Noam, 2005) that thwarts efforts to provide long-term professional development. Even when science-oriented professional development is offered, it tends to be limited in terms of time and material resources, and of variable quality (e.g., Noam et al., 2008).

**Science Instructional Materials**

The term *instructional materials* encompasses a wide range of resources that can be used by educators to plan for and enact learning experiences for students. In general, they are the concrete resources – activity descriptions, lesson plans, and curricular modules – that provide educators with activities and guidance to help students accomplish particular aims (Ball & Cohen, 1996). In science education, these materials can take many forms including commercially-based activity books that provide collections of science experiments or activities, science project kits such as butterfly hatching kits or model rocket kits, media resources such as educational science videos, trade books such as children's science books, and stand-alone lesson plans and activities downloaded from the Internet. They also can take the form of curriculum materials that organize activities and lessons into a coherent sequence of experiences that support learning over an extended period of time, usually over days or weeks, but sometimes over months and even years. While instructional materials can vary widely in design and purpose, an essential characteristic is that they provide some level of pedagogical support to educators (Ball & Cohen, 1996).

An important part of science instruction is using materials purposefully to make science accessible for students (Harris & Rooks, 2010). Instructional materials have been widely acknowledged for their central role in supporting learning in school-based environments (Ball & Cohen 1996) and have had a role in out-of-school learning environments, too (Katz & McGinnis, 1999). Well-designed materials with embedded support features can help educators with creating particular kinds of learning experiences (Singer, Marx, Krajcik, & Clay-Chambers, 2000) and even provide opportunities for educators to learn themselves as they teach (Davis & Krajcik, 2005). Support features can take the form of steps to follow, rationales for suggested actions, prompts or questions for use during instruction, and descriptions of outcomes to expect. Carefully designed support features have clear advantages – they can provide background information on science content, give guidance on arranging the learning environment, suggest strategies for interacting with students, and help educators anticipate student thinking. Of course, not all instructional materials are designed well. Some can be overly prescriptive, thereby diminishing the decision-making role of educators and the autonomy of students (Shulman, 1983). At the other end of the spectrum, underspecified materials can make it difficult for educators to envision how the learning experience should unfold (Kauffman et al., 2002).

Educators' use of instructional materials has been a focus of research in school settings and much of this research highlights that educators must thoughtfully interact with materials to make instructional decisions that meet the needs of their students. Following lesson or activity plans step-by-step may not lead to a successful learning experience for students (Davis & Varma, 2008). Likewise, straying too far from the lesson or activity structure risks that students will benefit less from the materials or not entirely meet the learning goals of the activity. Thus, in order to enact instructional materials effectively, it is important for educators to make interpretations and modifications consistent with the purposes and structures of the materials and consistent with their youths' learning needs and interests. These types of decisions, along with deciding how and when to enact lessons, are part of the important planning process that all educators must go through (Ben-Peretz, 1990). To date, there has been little research conducted on the role of instructional materials in supporting ambitious afterschool science.

## Study Context

The work reported here is part of a multi-year study designed to investigate the nature of afterschool science offerings in a statewide afterschool program system in California, including the sources of support for science programming and afterschool staff development at program sites. California's After School Education and Safety (ASES) program supports "locally driven" afterschool services at schools and in other community settings. Afterschool sites within the system are organized at the community level and run by partnerships between schools and afterschool providers, typically youth and community-based organizations. More than 4,000 afterschool sites are funded through the program and serve over 400,000 youth in grades K-9 each year. Each ASES site serves children from a partner public school; only schools with 50% or more of their students eligible for free or reduced-price lunch can participate in the program. Most sites (89%) are affiliated with elementary schools that serve students from Kindergarten through 5$^{th}$ or 6$^{th}$ grade. In the present study, we sought to better understand the types and range of science instructional materials in use at the afterschool sites serving elementary-aged children, the kinds of supports provided within these materials, and how afterschool staff used the materials to plan and enact science. Our research questions were:

1. What are the types and range of the science instructional materials used by staff and participants across sites of a publicly funded statewide afterschool program?
2. What are the support features of the science instructional materials used by staff and participants in the afterschool program?
3. How do staff members select and use science instructional materials to plan and enact science activities at their afterschool program sites?

## Methods

To address our research questions, we designed and administered a survey to a sample of afterschool sites serving elementary-aged children within the statewide ASES program. The afterschool science survey asked site coordinators to report on their site's science offerings, including the science instructional materials used by staff and participants. Next, we categorized the range of instructional materials identified by sites in the survey data. We then selected and gathered a representative sample of instructional materials and conducted an analysis of support features. Finally, we conducted semi-structured interviews with a sample of afterschool site personnel on how they selected materials and how they used them to plan for afterschool science.

**Administering the Afterschool Science Survey**

The afterschool science survey contained questions on frequency of science offerings and typical activities, types of instructional materials used, supports for activities, partnerships with science providers, and contextual factors related to capacity to deliver science instruction, such as staff at the sites and their qualifications. It also included questions regarding how decisions are made about science programming at the site level, including the staff person(s) responsible for selecting materials, activities, and science topics, and what factors shape their decisions.

***Sample.*** To select our survey sample, we collected a stratified random sample of urban and rural ASES sites, with sites across the two strata matched on school-wide demographics and achievement variables. A stratified random sample of 600 sites was drawn from the roughly 3,700 elementary sites that comprised 89% of all the publicly funded afterschool sites in California's ASES program at the time of the administration of the survey.

Comparison of the survey sample to the total population of ASES elementary afterschool sites indicated that the two groups were equivalent in terms of proportion of students eligible for free or reduced-price lunch, average Academic Performance Index (API) scores, average parental education, proportion of their school's teachers who were credentialed, and proportion of students in their school identified as gifted/talented. It is important to note, however, that the ASES elementary school-age population itself differs from the population of California elementary schools in a number of ways. Because only schools with more than half of their students eligible for free or reduced-price lunch are eligible for ASES afterschool programming, ASES elementary sites tend to have more non-white students, lower API scores, and fewer students identified as gifted/talented compared to California elementary schools as a whole.

***Procedure.*** The survey was sent to 600 ASES site coordinators (i.e., on-site program supervisors) at each selected afterschool site during the 2010-2011 school year. The survey was administered both online and on paper, with the majority of respondents completing the survey online. The survey was in the field for a total of 15 weeks; 426 site coordinators completed the survey (71% response rate) during this time period. After eliminating incomplete surveys and surveys with errors, the final sample was 415 surveys.

## Categorizing the Types of Instructional Materials

On the survey, site coordinators were asked whether or not they had offered science at their program site during the school year. Coordinators who indicated that they offered science were asked to name up to three different science instructional materials that were in use at their sites and that were representative of the kind of science resources typically used by staff; to briefly describe them; and to identify the source and publisher. We used this survey data to identify and categorize the types of instructional materials used by afterschool program sites.

***Selection***. We filtered our set of survey responses to create a subsample of program sites that had listed science instructional materials. First, we filtered on whether and how often sites offered science. From our 415 survey responses, 380 afterschool sites reported offering science. Next, we filtered for whether the sites had offered science during the school year in which we administered the survey and 294 sites remained. Finally, we filtered for whether the remaining sites listed science materials, and found that 159 sites nominated at least one material used in their after school science programming. This sample represented more than half of the sites that offered science during the school year and provided a rich and varied dataset for analysis.

***Categories.*** The materials identified from the survey responses were each sorted into one of three broad categories: (a) science curricular materials, (b) science enrichment materials, or (c) non-materials. *Curricular materials* were defined as science units or modules comprised of sequenced activities with specifications for enactment over multiple sessions. These materials included teacher/instructor guides and provided opportunities for science learning over an extended period of time. *Enrichment materials* encompassed a broad array of stand-alone lessons and activities designed for short-term use. Instructional materials that were sorted into the enrichment category included pre-packaged science projects, stand-alone activities or science lesson plan activities drawn from websites or books, and science trade books or media that were used to support science learning. These materials were typically not based on a logical learning sequence over time (e.g., related topics over multiple sessions that build upon each other) even though some activities within the books and websites were organized by science topic. *Non-materials* were defined as responses that were not science instructional materials or instructional activity resources for enacting science with children. These responses typically were science topics such as “weather” or “insects” that did not include any accompanying information regarding the instructional materials, or were externally delivered science events and fieldtrips.

We further delineated material types within our two broad focal material categories. For Curricular materials, we sorted each into one of three subcategories: (a) Out-of-school curricula (C1), (b) School-based curricula (C2), and (c) Context-independent curricula (C3) where the material was developed for cross-setting use (i.e., either in-school or out-of-school contexts). Enrichment materials were sorted into one of five subcategories: (a) Science lesson or activity plans from websites (E1), (b) Science lesson or activity plans from books (E2), (c) Trade book or media (E3), (d) Pre-packaged science project (E4), and (e) Site-developed material or activity (E5). Materials identified from the survey responses that did not have sufficient information to assign them to a materials category were designated as “not codable for material type”.

***Procedure***. The 159 sites nominated a total of 275 science instructional materials. All the nominated materials were identified and collected as either a digital or physical copy. As a first step in the analysis, the nominated materials were independently coded into the 8 categories listed above by two researchers, one who categorized the full set of materials and another who categorized a randomly selected subset of the materials (20%, n = 55). Afterwards, the two researchers met to compare their categorizations, check for reliability, and calibrate their decision rules. When both were uncertain about a categorization, a third researcher provided judgment to help clarify and make a decision. As part of this process, the research team modified and refined the categories and their parameters. We then conducted a second round in which the two researchers revisited category assignments and either confirmed or reassigned materials based on the refined category parameters. The inter-rater agreement was 87%. Differences were resolved through discussion and consensus to reach a final categorization for each material.

**Coding the Support Features of the Materials**

***Selection of materials.*** We used the results from our categorization of the instructional materials as the basis for selecting a subsample of materials for further analysis. We purposefully selected a proportional number of materials from each of five subcategories – the three subcategories of curricular materials (out-of-school materials, school-based materials, and context-independent materials) and two subcategories of enrichment materials (lessons/activities from websites [E1] and lessons/activities from books [E2]) – that were representative of the majority (73%) of the materials in the overall material sample. We also ensured that the types of materials selected for coding were representative of the overall pool of nominated materials. Of note is that other enrichment subcategories did not lend themselves to further sampling and coding (i.e., site-developed materials [E5] would not be generalizable and trade books [E3] and pre-packaged kits [E4] did not occur frequently) and thus were dropped from subsequent analysis. In all, 37 instructional materials were selected for in-depth support feature coding.

***Coding Scheme.*** We designed a comprehensive coding scheme to identify and analyze the full range of support features provided within the instructional materials. This coding scheme was based on the strands from the *Learning Science in Informal Environments* report (NRC, 2009) and *Taking Science to School* (NRC, 2007), as discussed in more detail below. The scheme measures instructional support across four dimensions: (a) content and structure of the activities, (b) usability for facilitators and children, (c) engagement for children and relevance to their lives, and (d) promotion of scientific thinking, reasoning, and practice. For each dimension we specified a set of indicators for identifying support features within science instructional materials. A total of 61 codes represented the indicators for these four dimensions (see appendix).

Dimension 1, content and structure of the activities, examines the features that help facilitators to structure the science activities into a coherent “storyline” for children to move along a pathway for learning. Indicators for this dimension are 14 codes that focus on such features as science learning goals, sequence and pacing, and allocating time for doing science. Dimension 2, usability, addresses features in materials that support enactment and accessibility for facilitators and children. This dimension contains 23 codes that address facilitator features, such as preparation for instruction, guidelines for orchestrating activities, and educative supports for effective enactment, as well as support features for children, such as directions and materials (e.g., activity sheets, science notebook, directions/procedures, and posters), and specialized supports for children of diverse backgrounds and abilities to access the science.

For Dimension 3, engagement for children and relevance to their lives, we established indicators for identifying features that attempt to bridge science to children's everyday social and physical world. These 11 codes include features for facilitators to situate learning in a context, such as a driving question, dramatic scenario, real-world situation, or compelling problem/issue; help children use their prior knowledge and interests for learning, and provide opportunities and support for children to make choices. Dimension 4, promotion of scientific thinking, reasoning, and practice, encompasses supports and prompts for facilitators to help children to think and reason about their science experiences and to effectively reflect on their learning. The 13 codes for this dimension include supports for facilitators and children to engage in science practices and productive discourse that encourages collective scientific thinking via discussion and debate.

The dimensions were constructed from the National Research Council's research synthesis reports on learning science in school and out-of-school settings – *Learning Science in Informal Environments* (NRC, 2009) and *Taking Science to School* (NRC, 2007). Indicators were vetted against a review of research literature to provide an argument for the selection and inclusion of specific indicators under each dimension. It is important to note that the purpose of this coding scheme was not to determine the quality of instructional materials, but to identify important features of materials that could support the enactment of science.

***Procedure***. We collected the full set of instructional materials that comprised our subsample for coding. We used a small subset of the materials for refining the coding scheme and training on its use. Two researchers were trained on using the coding scheme and went through multiple practice rounds of coding with this smaller set. Once sufficient agreement –

above 70% on the majority of the codes (Stremler, 2004) – was reached in the practice rounds, each researcher was randomly assigned approximately 60% of the materials in the main set, with 20% of the materials coded by both researchers for reliability checking. The researchers met to compare codes, reach consensus on any disagreements, and assign final codes for all indicators. When both researchers were uncertain about a piece of evidence for coding a support feature, a third researcher provided judgment to help clarify and reach agreement.

We examined the 37 instructional materials at the lesson or activity level and conducted double sampling of lessons/activities when a given material included more than one lesson in order to account for some amount of range within the material (such as a book of science experiments or a textbook). In total, we coded 67 lessons/activities: (a) 17 website-based lessons/activities (E1), (b) 32 book-based lessons/activities (E2), (c) 8 out-of-school curriculum-based lessons/activities (C1), (d) 8 in-school curriculum-based lessons/activities (C2), and (e) 2 context-independent curriculum-based lessons/activities (C3).

**Interviewing Afterschool Site Staff**

Our final step to understanding the role of instructional materials in afterschool science was to examine how staff members selected materials and the materials' role in planning for science. We conducted interviews with staff from 13 afterschool sites to better understand how these materials were situated within the science offerings provided at afterschool sites.

***Selection of sites.*** Our selection process began with a sample of 119 candidate sites whose survey responses indicated that they had two or more sources of support for science, offered science at least once a week, and used science instructional materials. We further narrowed down our list by identifying sites that provided the most frequent science offerings and collectively represented a wide range of materials. We then contacted 36 of the most promising sites, resulting in 13 sites with staff members who agreed to participate in interviews.

***Interview protocol***. We developed a semi-structured interview protocol that addressed such topics as staff and site capacity for offering science, the process of selecting instructional materials, and how sites used materials to plan and prepare for science. To learn about staff capacity, the protocol included questions about site coordinators' and facilitators' experiences and perspectives on leading science activities with children, backgrounds in science, and training for afterschool science. Questions about site capacity included frequency of science offerings, and the physical space, materials and other resources available for science. The protocol also prompted interviewees to describe a recent or upcoming science activity as an entryway to conversation about materials selection and the activity planning process. Questions during this phase of the interview probed for the kinds of instructional materials typically used, the reasons and criteria for selecting them, constraints influencing the material selection process, the ways in which the materials were used to plan, and how they were used to enact science with children.

***Procedure***. Interviews were conducted via phone with afterschool site coordinators or facilitators who had knowledge of the process of selecting materials and planning for science at their sites. The interviews, lasting 45 to 60 minutes, were audio-recorded and then transcribed.

We used an inductive approach to identify themes within and across and transcripts. Topic codes were assigned to statements made related to different topics in each set of interview data, then compared across interviews, and finally condensed into a summary format. Each topic summary included exemplars that were representative of the interview responses. This process was carried out by two researchers who independently assigned topic codes and then met to discuss, resolve differences, and construct the summaries.

## Results

**Types and Range of Science Instructional Materials**

Although 159 sites nominated materials in their survey responses, 13 sites were dropped from subsequent analysis due to their nominations being “non-materials” (i.e., not instructional materials). After this filtering, our analysis focused on 249 instructional materials nominated by 146 afterschool sites. Of the 146 sites, 85 sites reported one material, 28 sites reported two materials, and 33 sites reported three or more materials. As shown in Table 1, a majority of these materials, 71.9%, were science enrichment materials and 28.1% of them were science curriculum materials. Of the 179 science enrichment materials reported, most were lessons/activities from either websites or books. Out-of-school and school based curricula were nearly evenly divided and comprised most of the materials in the curriculum category.

Insert Table 1 about here

*Use of materials by sites*. We examined the range of materials that afterschool sites reported using and found that 106 (73%) of the 146 sites reported using at least one type of enrichment material while 61 sites (42%) reported using at least one type of curricular material. Regarding curriculum materials, 30 sites (20.5%) used out-of-school (C1) materials, 28 sites (19.2%) used school-based materials (C2), and 6 sites (4.1%) used context-independent materials (C3). On the enrichment side, 47 sites (32.2%) used lessons/activities from websites (E1), 38 sites (26.0%) used lessons/activities from books (E2), and 29 sites (20.0%) used their own site-developed materials (E5). The two other types of enrichment materials (E3 and E4) were used by a much smaller number of sites, 4.8% and 13.0% respectively.

Across the 146 sites that reported on material use in the survey, 40 sites (27.4%) used only curriculum materials, while 85 sites (58.2%) used only enrichment materials. Just 21 sites (14.4%) used a combination of the two categories. In general, sites used only one category of material, even if they used multiple materials in their program, and this was typically multiple enrichment materials. There were 61 sites that reported using multiple materials at their site and about one third of these sites reported using both curricular and enrichment materials.

**Support Features of the Instructional Materials**

In our examination of the support features found in the instructional materials, we found that, on the whole, curricular materials had more support features than enrichment materials. Additionally, materials that had a relatively high number of support features from one dimension on the coding scheme usually had a relatively high number of support features in the other dimensions. In other words, most materials either had many of the support features of interest or very few support features. Of note is that there were some features that were rarely seen across the full spectrum of materials. Both curricular and enrichment materials, for instance, were found to have minimal support features addressing social-emotional learning goals (i.e., engagement, motivation, and attitude towards science); use of science notebooks or journals to record work; prompts to coordinate prior knowledge with new knowledge; supports or prompts to encourage reflection on learning; strategies for facilitators to encourage children to listen and build on each others' ideas; and opportunities for children themselves to design experiments or investigations. We performed a principle components analysis (PCA) on the dataset to see if we could reduce the dimensionality of the data. The first two dimensions only captured 32% of the variance of the dataset. Although the scores across the dimensions are correlated, which specific features materials are coded for are not – which is why the variance captured in the PCA is relatively low.

We examined the main differences in support features across the categories and sub-categories of instructional materials for each of the four dimensions of instructional support: (a) content and structure of the activities; (b) usability for facilitators and children; (c) engagement for children and relevance to their lives; and (d) promotion of scientific thinking, reasoning, and practice. The accompanying box and whisker plot for each of the four dimensions shows each of the sub-category's median scores (i.e., the number of support features in that dimension) as well as the first and third quartiles and any outliers.

*Content and Structure of the Activities*

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Insert Figure 1 about here

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Regarding the first dimension, content and structure of the activities, Figure 1 shows that lessons and activities in the two curriculum categories scored much higher on support features than the lessons and activities in the enrichment categories. This trend holds for all four of the dimensions, but it is especially pronounced for this dimension. Of particular note are the high scores among the school-based materials, which perhaps are to be expected on this dimension since it captures a focus on content and structure, which are hallmarks of materials for school settings. Among the lessons and activities from books (E2), Figure 1 shows a broad range on this dimension, highlighting the wide degree to which materials in this sub-category vary in terms of support features for content and activity structure. Overall, curriculum materials were more likely than enrichment materials to identify the age/grade level appropriateness of the lessons or activities, specify an expected time frame for completing them, and provide a clear sequence to the lessons or activities. Also of note is that curriculum materials were more likely to include scientific practices among learning goals. Other support features in this dimension were either similarly present or absent across the two categories of materials.

*Usability for Facilitators and Children*

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Insert Figure 2 about here

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Regarding usability for facilitators and children, the second dimension, Figure 2 shows that the lessons and activities found in out-of-school and in-school curriculum materials scored much higher in support features than the lessons and activities from websites and books. Curriculum materials were much more likely to include notes and/or tips for facilitators within lessons or activities, activity sheets for children, and targeted support for English Language Learners. Curriculum materials were also more likely to suggest multiple ways (i.e., different modes) for children to engage in science, multiple grouping formats (e.g., pairs, whole group, individual) for children to work on tasks, and multiple ways for children to showcase their learning. The other support features were either not present in all of the materials or present in relatively similar frequencies in all of the materials.

*Engagement for Children and Relevance to Their Lives*

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Insert Figure 3 about here

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As illustrated in Figure 3, the lessons and activities in the two curriculum categories scored higher in support features for the third dimension, engagement for children and relevance to their lives, than the lessons and activities in the enrichment categories. Both enrichment categories were very low on this dimension, highlighting the lack of support for instructional options for children, and lack of guidance for facilitators to help engage children in science. Quite differently, curriculum materials were much more likely to situate the learning in an engaging context, such as a dramatic scenario, real-world situation, or compelling problem/issue. Lessons and activities in both types of curriculum materials were more likely to provide suggestions for facilitators on how to connect science to the real world, provide opportunities and support for children to make choices that are consequential for engagement and learning, and provide guidance for facilitators to help children make choices or carry out plans. Other support features in this dimension were similarly present or absent across the two categories of materials.

*Promotion of Scientific Thinking, Reasoning, and Practice*

Insert Figure 4 about here

For the fourth dimension, promotion of scientific thinking, reasoning, and practice, Figure 4 shows that the lessons and activities across all the curriculum and enrichment categories scored much more similarly to each other than on the other three dimensions. Moreover, all four materials categories had high variation, especially out-of-school curriculum materials. Still, within this dimension, curriculum materials were more likely to provide guidance to facilitators to help children think, reason, and reflect about science; questions for facilitators to elicit ideas, questions, and contributions during discussion; and strategies for facilitators to encourage children to make claims, weigh evidence, collect, analyze, and interpret data, make and critique scientific explanations, and communicate or present findings. Other support features in this dimension were either similarly present or absent across the two categories of materials.

*Differences Within Categories*

In our closer examination of the two types of materials from the enrichment category, several notable differences emerged. A rationale for learning goals was more likely to be included in lessons or activities from books (E2) than to be included in lessons or activities from websites (E1). However, E1 materials were more likely to situate learning within a context and to include prompts to encourage or support learner interest in science than were E2 materials.

There were also distinctions between the features likely to be included in out-of-school (C1) and school-based curricula (C2). C1 materials more often included materials for activities for the facilitators to use, materials for children to use, and prompts to encourage/support an interest in science. C2 materials more often included a rationale for learning goals, suggestions for adapting/extending activities, directions/procedures for children to follow, explanations situating learning in a context, opportunities for children to make choices consequential for learning, and guidance for facilitators to help children make choices or carry out plans.

**Staff Use of Instructional Materials**

Our interviews with coordinators and facilitators across sites provided insight into how instructional materials were selected and used for planning and enacting science. Site coordinators and facilitators reported that they were guided by a number of considerations when reviewing possible lessons and activities. Considerations included the cost of resources needed to implement; whether the materials included activities that children would enjoy and be capable of doing; the alignment of the lessons or activities to the skills, knowledge, and interests of staff; and the complexity of planning and implementing with the materials. Site coordinators and facilitators emphasized that they reviewed materials with an eye toward selecting those that they believed would help staff enact engaging and meaningful science experiences with children. In this endeavor, they primarily focused attention on individual lessons and activities, and made judgments about how easy or difficult a “lift” each would be for staff to use to create a science experience. Site coordinators and facilitators, while being purposeful in selecting materials that they perceived would be supportive of staff, did not report that they looked for specific support features, such as pedagogical supports, within materials. Rather, they attended to broad aspects related to the feasibility of staff implementing the materials, such as clear instructions, familiar or easy to grasp science content, and minimal time for preparation and cleanup.

The site coordinators and facilitators we interviewed all reported that they typically planned for short term, stand-alone science experiences. This was the case for coordinators and facilitators whose sites relied on enrichment materials as well as for those whose sites primarily used curricular materials. The general approach shared by coordinators and facilitators across sites was to identify lessons or activities within materials to support planning and implementation of one afterschool science session at a time. Some reported that they organized their selections around topics or themes, such as environmental sustainability, and sometimes chose multiple activities to match with a particular theme, but they did not select and plan activities for sequenced sessions that would explicitly link the learning experiences or build upon one another. Coordinators and facilitators who used primarily curricular materials reported that they used these materials flexibly and primarily as resources for finding stand-alone activities.

Across sites, coordinators and facilitators reported that they conducted searches on the Internet to find lessons and activities. Those who mainly used enrichment materials at their sites identified the Internet as the primary source for lessons and activities, followed by science activity books. Coordinators and facilitators who mostly relied on curricular materials also reported that they conducted Internet searches to find supplemental lessons and activities. Similarly, they typically did not search online for sequenced science experiences and instead sought to identify promising easy-to-implement stand-alone science activities.

## Discussion

Afterschool site coordinators nominated a wide range of instructional materials that fell into two large categories: curricular materials and enrichment materials. They reported using primarily enrichment materials in the form of stand-alone lessons and activities selected from books and websites. In our analysis, we found that enrichment materials had fewer support features for facilitators and children that could aide in planning and enactment. Curricular materials, both those designed for school settings and those designed for out-of-school settings, were reported to be used much less frequently, yet were found in our analysis to be much more likely to have support features aligned with current recommendations for quality afterschool science (e.g., NRC, 2009) and with learning goals reported by site coordinators and facilitators.

Of note is that not all of the enrichment materials we analyzed were lacking in support features. There were some materials that did include support features for facilitators and children. However, among those enrichment materials that did include support features we found that they varied greatly in the number and nature of the supports. By far, the predominance of enrichment materials used across afterschool sites included minimal support features.

In our analysis of materials that were expressly designed for afterschool settings, we found that they often included support features that aimed to address the constraints and needs of the typical afterschool space. For instance, these materials tended to include flexible time frames for enacting activities, guidance for organizing and interacting with groups of children, science background information described for a layperson, and easy-to-learn strategies for encouraging children to collaborate and share ideas. One set of afterschool materials we reviewed included a collection of sequenced sessions so that children could build their science understanding over time, but these same materials were also designed so that children's participation in any one session was not dependent upon completing the prior session. In this way, the materials accommodated flexible attendance – an important characteristic of the afterschool setting.

Despite having an attractive range of support features, we found that materials expressly designed for afterschool settings were not widely used across afterschool sites. From our interview data with site coordinators and our past case studies of afterschool programs (Lundh, House, Means, & Harris, 2013), we know that there are many factors that site coordinators weigh when deciding on instructional materials. These factors include cost and ease of access to the materials, perceived time and resources needed to plan and implement, alignment to the skills and interests of facilitators, and the enjoyment level for children. Many of the afterschool materials in our review were found to include features that appeared to match well with what site coordinators reported as important for the high-quality implementation of science at their sites. Yet, we also know that site coordinators and facilitators tended to plan for the short term and preferred stand-alone science activities. They conducted searches on the Internet to identify and develop or refine activity ideas rather than to identify sequenced materials or comprehensive instructional resources. Thus, the low uptake of afterschool instructional materials may be due in part to limited awareness of the value of them. Our research shows that by relying primarily on stand-alone activities from books or websites, facilitators likely miss out on support features that could help them enact meaningful science experiences with children.

It is also important to emphasize that while a particular instructional material might score high across multiple dimensions it does not necessarily follow that the material will be easily enacted by afterschool staff. The usability of instructional materials in real-world afterschool settings may depend on a range of factors, such as facilitator preparedness, time for planning and enactment, and fit with program goals and routines. For these reasons, it would not be suitable to select materials solely on the basis of dimension scores. Rather, we hold that the dimensions can provide good guidance when reviewing materials for their fit with current perspectives on how learners can best be supported in out of school settings, as described in the NRC's synthesis report (NRC, 2009) on informal science learning.

An important limitation of our study is that we did not examine how the materials were actually implemented at afterschool sites, nor did we examine whether or not facilitators were using the support features that were available to them and/or what features were most beneficial and in what ways. In recent years, the science education community has been building a rich knowledge base on the role of educative features in curriculum materials (e.g., Arias, Bismack, Davis, & Palincsar, 2016; Wilson, Schweingruber, & Nielsen, 2015). Much of this work has focused on school science curriculum materials. While there is much that can be learned from formal settings, there is a great need for studies on instructional materials and their effectiveness in informal environments. Such research could help the science education community better understand the ways in which materials can be designed to effectively support science learning experiences in everyday afterschool programs.

## Conclusion

There is broad agreement that afterschool has tremendous potential for offering rich science learning experiences for children. Well-designed instructional materials, with features that align with current perspectives of what makes for quality afterschool science, could help afterschool facilitators and children realize that potential. Instructional materials are but one component of a larger system of resources necessary for ensuring high quality science programming. They are, however, an essential part of that system and if designed with the unique affordances of the afterschool space in mind, they hold promise for supporting facilitators in implementing meaningful experiences that can help all children become engaged and enthusiastic learners of science.

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Table 1
*Categorization of instructional materials (N = 249)*

| Category | Code | Material Type | Frequency | % |
|---|---|---|---|---|
| Curriculum | C1 | Out-of-school curricula | 32 | 12.9 |
| | C2 | School-based curricula | 30 | 12.0 |
| | C3 | Context-independent curricula | 8 | 3.2 |
| Enrichment | E1 | Lessons or activities from websites | 62 | 24.9 |
| | E2 | Lessons or activities from books | 50 | 20.1 |
| | E3 | Trade book or media | 7 | 2.8 |
| | E4 | Pre-packaged science projects and kits | 21 | 8.4 |
| | E5 | Site-developed material or activity | 36 | 14.5 |
| | E | General enrichment (source unknown) | 3 | 1.2 |

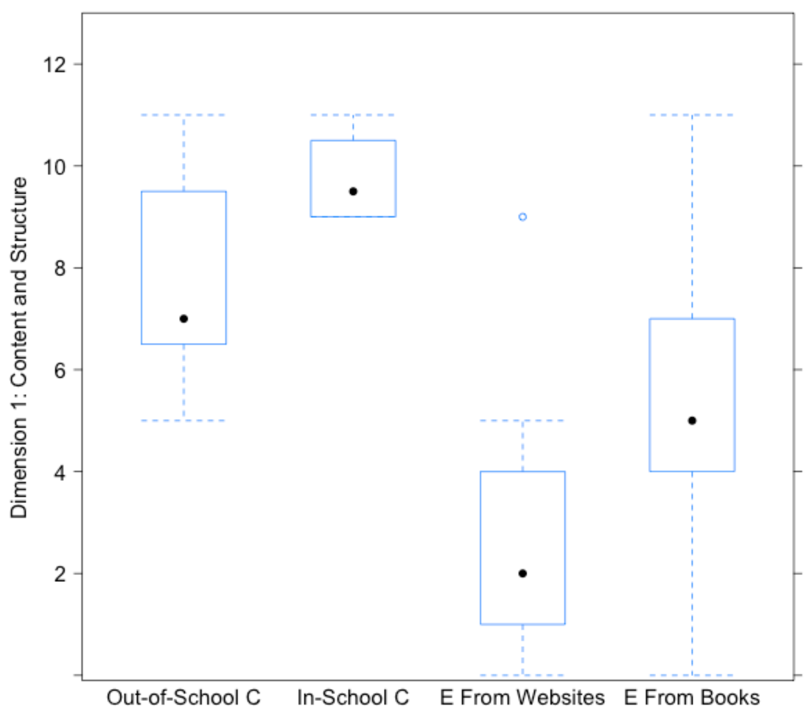


Figure 1.

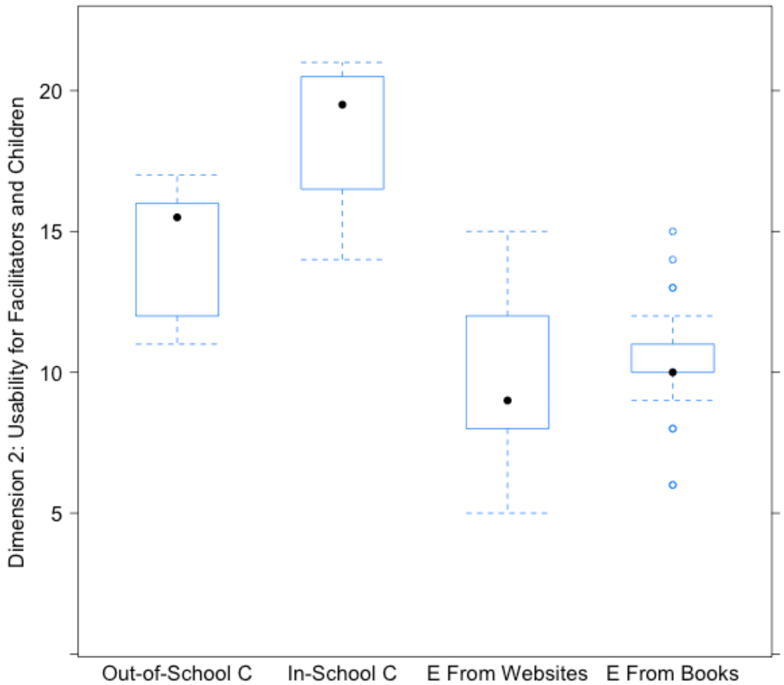


Figure 2.

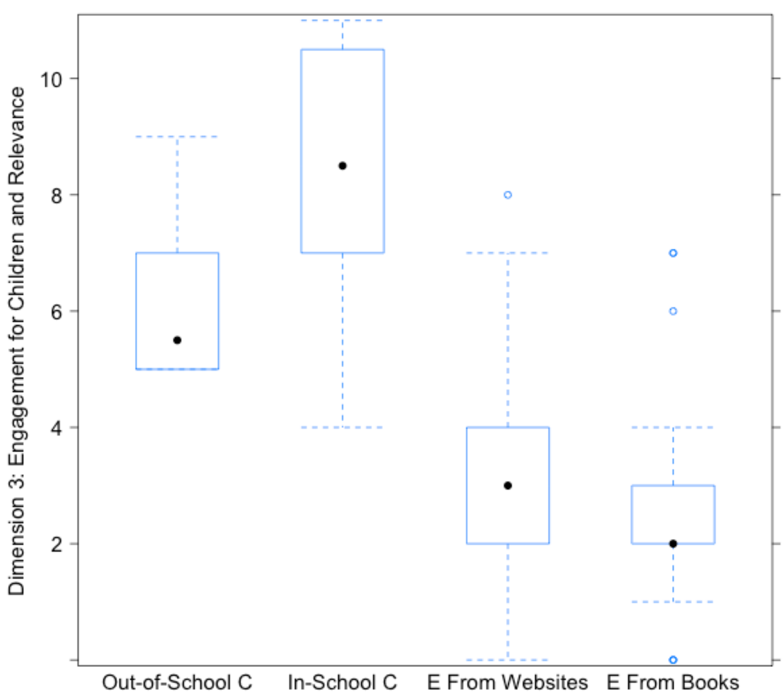


Figure 3.

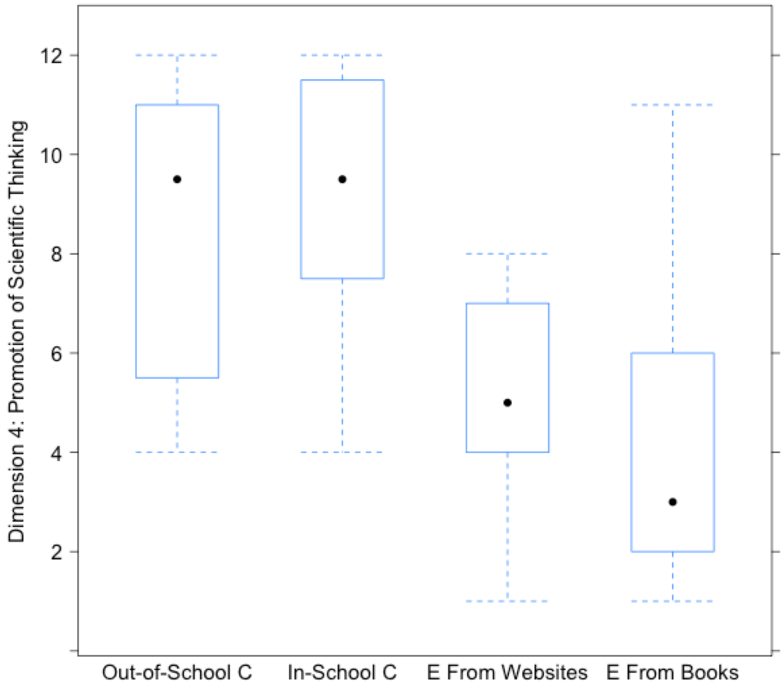
Dimension 4: Promotion of Scientific Thinking
12
10
8
6
4
2
Out-of-School C
In-School C
E From Websites
E From Books

Figure 4.

**Appendix: Materials Coding Scheme**

| **Dimension 1. Content and Structure of Activities** | | |
|---|---|---|
| Feature | Code | Indicator |
| 1.1. Science learning goals: *Does the material include explicit learning goals?* | 1.1.A1. | Identifies science content among its learning goals |
| | 1.1.A2. | Identifies science practice among its learning goals |
| | 1.1.A3. | Identifies engagement, motivation, attitude toward science among its learning goals |
| | 1.1.B1. | Science content learning goals are explicitly aligned to benchmarks/standards |
| | 1.1.B2. | Science practice learning goals are explicitly aligned to benchmarks/standards |
| | 1.1.B3. | Engagement, motivation, attitude toward science learning goals are explicitly aligned to benchmarks/standards |
| | 1.1.C. | Provides a rationale for the learning goal(s) |
| | 1.1.D. | The age/grade level is specified |
| 1.2 Activities: *Does the material include one or more activities and are they sequenced to help children make progress toward achieving key science learning goals?* | 1.2.A. | Stand-alone activity |
| | 1.2.B. | The activity is part of an organized group of activities (note how grouped, e.g., by topic, theme, chapter etc.) |
| | 1.2.C. | The activity is part of a logical sequence of activities that build toward more sophisticated understanding of science content and/or scientific practices |
| | 1.2.D. | Provides a rationale for the sequence of activities |
| 1.3 Time for doing science: *Does the material allocate time for learning science via investigations/projects?* | 1.3.A. | The activity extends beyond one session or connects to a prior or next activity |
| | 1.3.B. | Time frame is specified in the material for carrying out activities/tasks |

| **Dimension 2. Usability for Facilitators and Children** | | |
|---|---|---|
| Feature | Code | Indicator |
| 2.1 Guidance for facilitators: *Does the material include guidelines for enactment by the facilitator?* | 2.1.A. | Overview of the activity is included |
| | 2.1.B. | Describes materials and necessary preparation |
| | 2.1.C. | Provides materials for activities |
| | 2.1.D. | Step-by-step guidance for how to enact |
| | 2.1.E. | Safety guidelines |
| | 2.1.F. | Prompts for discussion/reflection |
| | 2.1.G. | Suggestions for adapting or extending activities |
| 2.2 Educative features: *Does the material include background information to support facilitator knowledge and practice?* | 2.2.A. | Background on content knowledge (e.g., glossary) |
| | 2.2.B. | Background on children's likely ideas, including misconceptions |
| | 2.2.C. | Notes/tips for facilitator (e.g., notes/tips for effective instruction, management, etc.) |
| 2.3 Support for children: | 2.3.A. | Provides science materials for children to use during |

| | | |
|---|---|---|
| *Does the material include supports for children to engage in scientific activity?* | | activities |
| | 2.3.B1. | Activity provides firsthand experiences with phenomena |
| | 2.3.B2. | Activity provides reading about science |
| | 2.3.B3. | Activity provides secondhand experiences (e.g., demonstration) |
| | 2.3.C. | Directions/Procedures for children to follow themselves |
| | 2.3.D. | Activity sheets are included |
| | 2.3.E. | Science notebook or journal for children to record work is included |
| 2.4 Accessibility for diverse populations: *Does the material provide multiple means for diverse populations to access the science?* | 2.4.A. | More than one way for children to learn (e.g., print materials, hands-on, video, etc.) |
| | 2.4.B. | More than one way for children to work (e.g., individual/collaborative) |
| | 2.4.C. | More than one way for children to showcase their learning |
| | 2.4.D. | Supplements or guidance for facilitators to adapt activities for children with diverse needs |
| | 2.4.E. | Supplements or guidance for facilitators to meet needs of English language learners (ELLs) |
| | 2.4.F. | Support for ELL in the materials provided to children (e.g., illustrations, translations, etc.) |

**Dimension 3. Engagement for Children and Relevance to Their Lives**

| Feature | Code | Indicator |
|---|---|---|
| 3.1 Connections to children's everyday lives: *Does the material attempt to bridge science to children's everyday social and physical world?* | 3.1.A. | Includes science tasks or activities that relate to children's everyday lives |
| | 3.1.B. | Situates learning in a context, such as a driving question, dramatic scenario, real-world situation, or compelling problem/issue |
| | 3.1.C. | Provides suggestions for community involvement and/or connections to life at home |
| | 3.1.D. | Provides suggestions for facilitators about how to connect science to the real world |
| 3.2 Leverage children's prior knowledge and interests: *Does the material provide prompts and support for facilitators to help children use their prior knowledge and interests for learning?* | 3.2.A. | Provides elicitation prompts for children's prior knowledge and interests |
| | 3.2.B. | Prompts for children to relate their prior knowledge and own ideas/interests to the activities |
| | 3.2.C. | Prompts to encourage children to coordinate their prior knowledge with new knowledge |
| | 3.2.D. | Prompts to encourage /support children's developing interests in science |
| 3.3 Choice for children: *Does the material include opportunities and support for children (individual* | 3.3.A. | Includes opportunities for children to make choices that are consequential for engagement |
| | 3.3.B. | Includes opportunities for children to make choices that are consequential for learning |

| | | |
|---|---|---|
| *or group) to make choices about the direction of their learning?* | 3.3.C. | Includes guidance for facilitators to help children make choices and/or carry out their decisions/plans |

| **Dimension 4. Promotion of Scientific Thinking, Reasoning and Practice** | | |
|---|---|---|
| Feature | Code | Indicator |
| 4.1 Thinking, reasoning, and reflection: *Does the material provide supports/prompts for children to think, reason, and reflect about science experiences?* | 4.1.A. | Supports/prompts for children to question, predict, observe, and/or explain |
| | 4.1.B. | Supports/prompts for children to reflect on their learning experiences |
| | 4.1.C. | Guidance for facilitators to help children to think, reason, and reflect about science experiences |
| 4.2 Collaborative discourse: *Does the material provide questions or strategies for facilitators to encourage productive conversation?* | 4.2.A. | Questions for facilitators to use to elicit participant ideas, questions, and contributions during discussion |
| | 4.2.B. | Strategies for facilitators to encourage children to listen to and build upon one another's ideas |
| | 4.2.C. | Strategies for facilitators to encourage children to make claims and weigh evidence during discussion |
| 4.3. Scientific inquiry practices: *Does the material include activities that engage children in a range of scientific inquiry practices?* | 4.3.A. | Pose and/or pursue researchable or investigable questions |
| | 4.3.B. | Design experiments and/or investigations |
| | 4.3.C. | Conduct experiments and/or investigations |
| | 4.3.D. | Collect, analyze, and interpret data |
| | 4.3.E. | Build and/or use models to represent phenomena, test designs, or show ideas/understandings |
| | 4.3.F. | Make and critique scientific explanations |
| | 4.3.G. | Communicate/present findings |